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CloudSat Annual Ops Review
Cloud Profiling Radar Status

May 6-7, 2019

Gregg Dobrowalski, Simone Tanelli
Jet Propulsion Laboratory, California Institute of Technology

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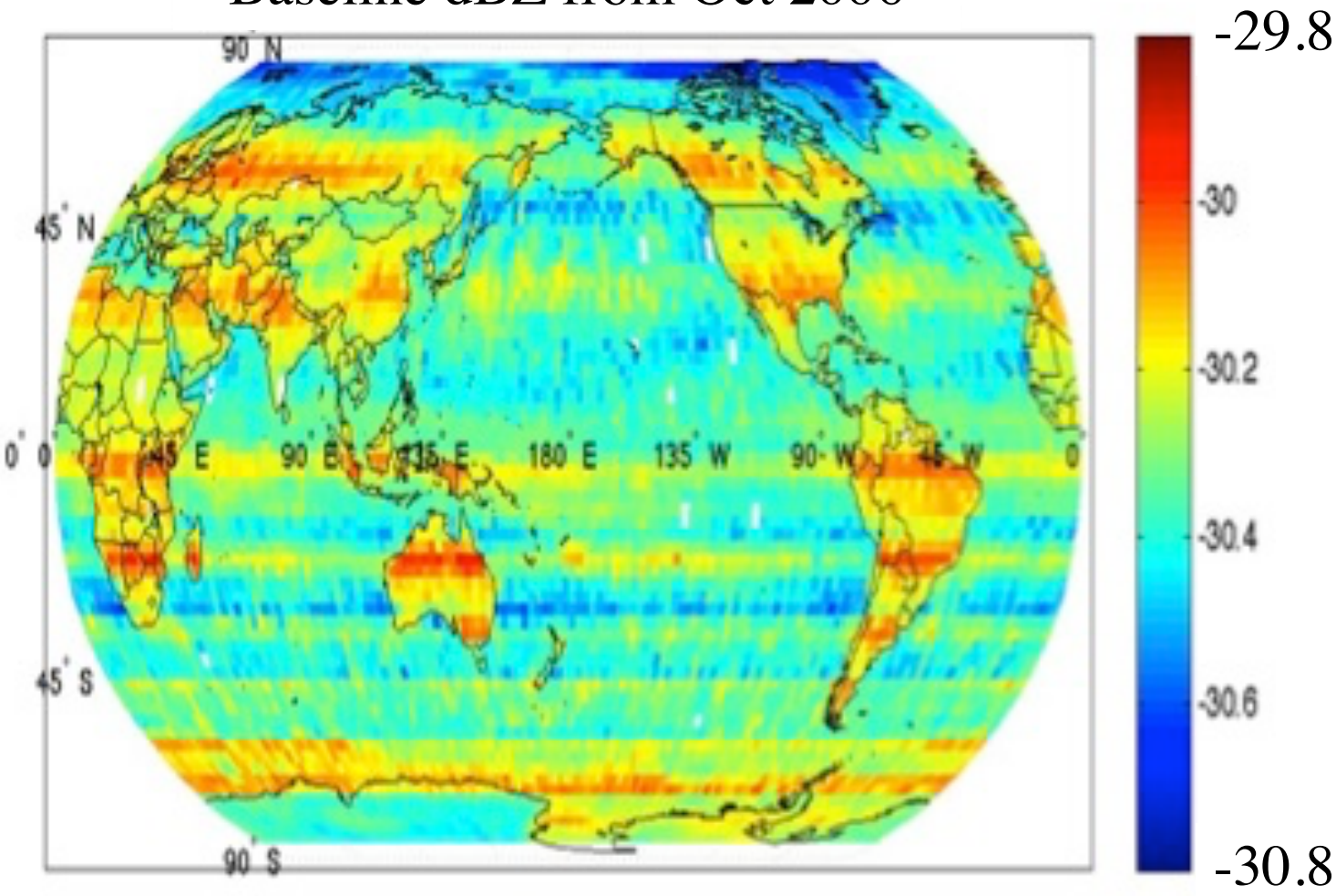
CPR Status: High Level Summary

- CPR is still performing above requirement after:
  - More than 13 years in orbit (aka: >6x original mission duration design)
  - More than 33K power cycles in orbit (~15 per day since Nov 2011)
  - All functions stable
- CPR is still on the primary amplifier (CPI's EIK + JPL's HVPS)
  - Current trends indicate there is a chance we'll want to switch next winter (see next several slides) if the EIK aging accelerates.
  - Analysis of long term trends in October 2019 will be used to make the call.
- CPR acquires data approximately 55 minutes every 99 (1 orbit) to avoid stressing the spacecraft battery
  - It starts transmitting about 8 minutes after the spacecraft emerges from the dark side. So, in MJJ we miss almost entirely Antarctica.
  - It stops transmitting less than a minute before entering the dark side. So we don't miss the Arctic.

Minimum Detectable Reflectivity Factor – Global view

Baseline dBZ from Oct 2006



CPR Minimum Detectable Reflectivity varies with the number of pulses sent (latitudinal banding) the temperature of the background (land-ocean-ice contrasts) and with the hardware performance.

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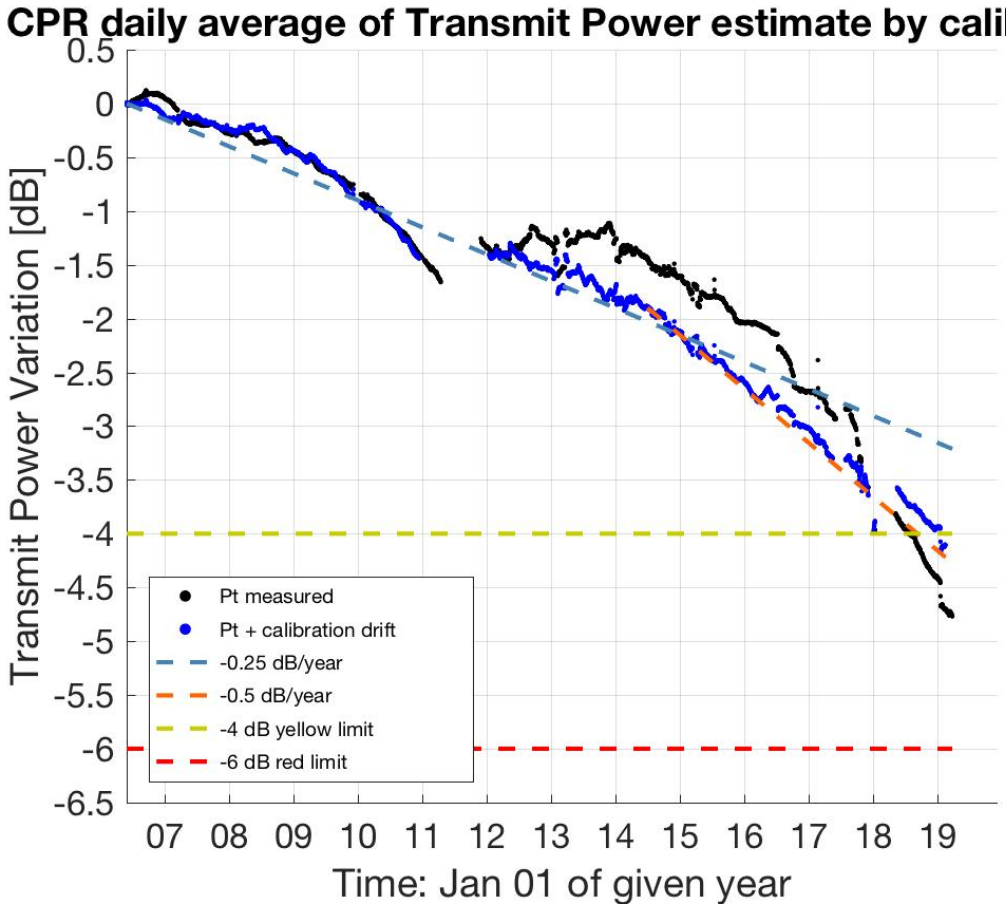
Minimum Detectable Reflectivity Factor – Since mission start

MDZ



Primary hardware performance is summarized by the blue curve to the that includes measured decline in transmit power and drift in calibration. Other minor contributions not included amount to less than 0.2 dB.

OVERALL as of **Jan 2018** the MDZ was estimated to be approx: -26 ±-0.5 dB with a rate of ~0.5 dB/year (in the prior 3.5 years)

OVERALL as of **Feb 2019** the MDZ was estimated to be approx: -26 ±-0.5 dB. **Note the blue curve trending down to nearly the same level seen one year ago.**

Yellow limit shown at -4dB corresponds to -26 dBZ minimum signal

Red limit shown at -6dB corresponds to -24 dBZ minimum signal

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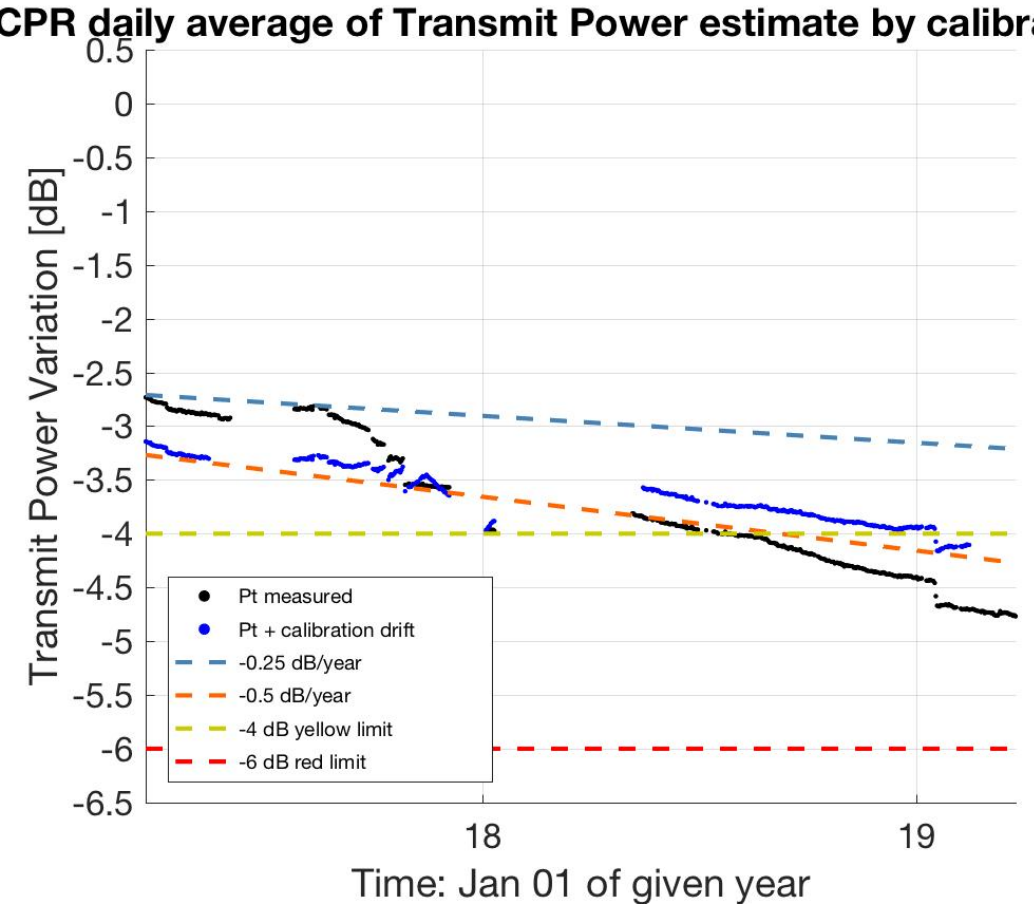
Minimum Detectable Reflectivity Factor – Past two years

MDZ



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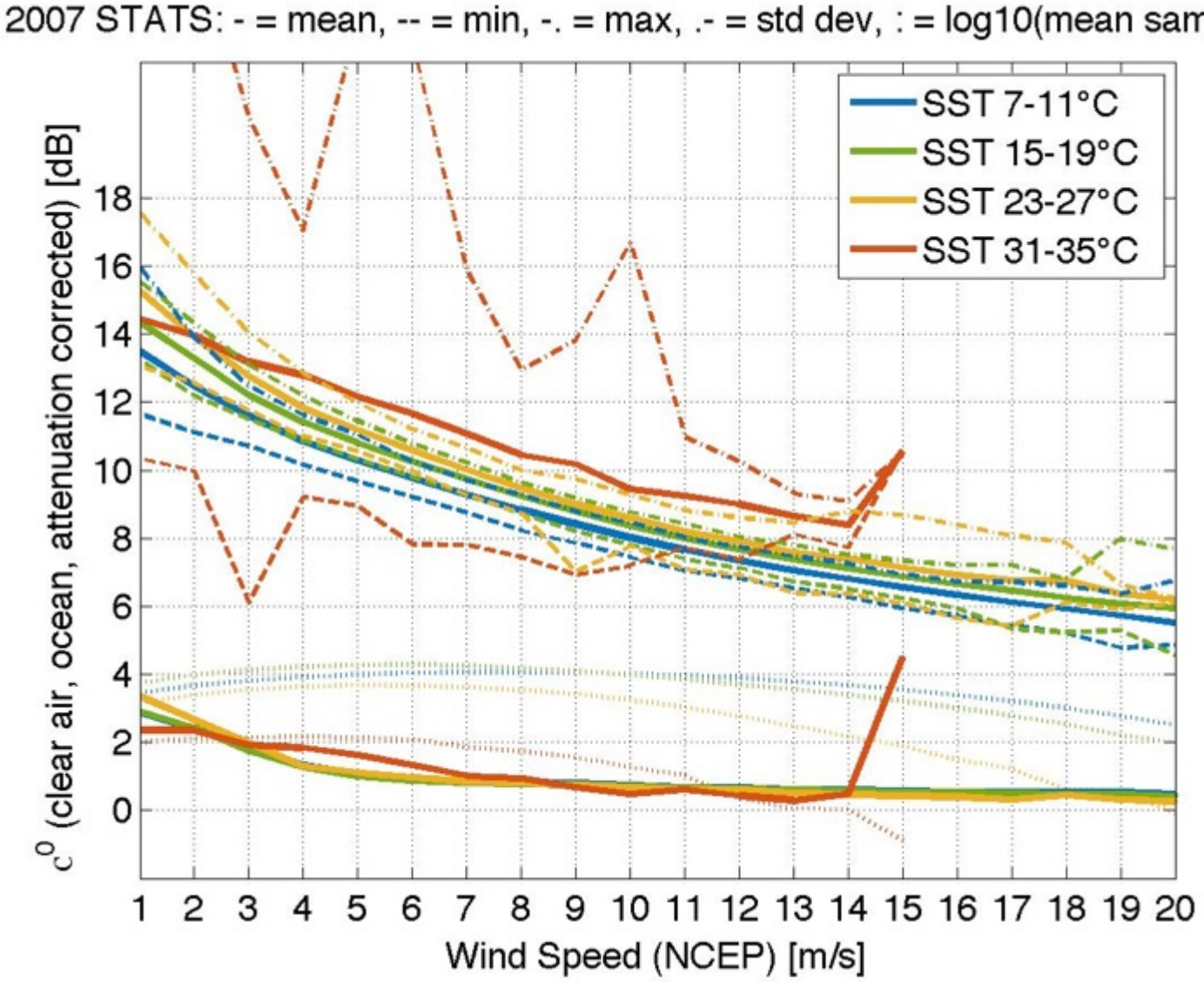
Absolute & Relative End-to-end Calibration Automation



These are the long term reference curves of ocean Normalized Radar Cross Section as function of wind speed and SST.

In the next slide the NRCS anomaly is defined as the difference between the observed NRCS and what is predicted by these curves.

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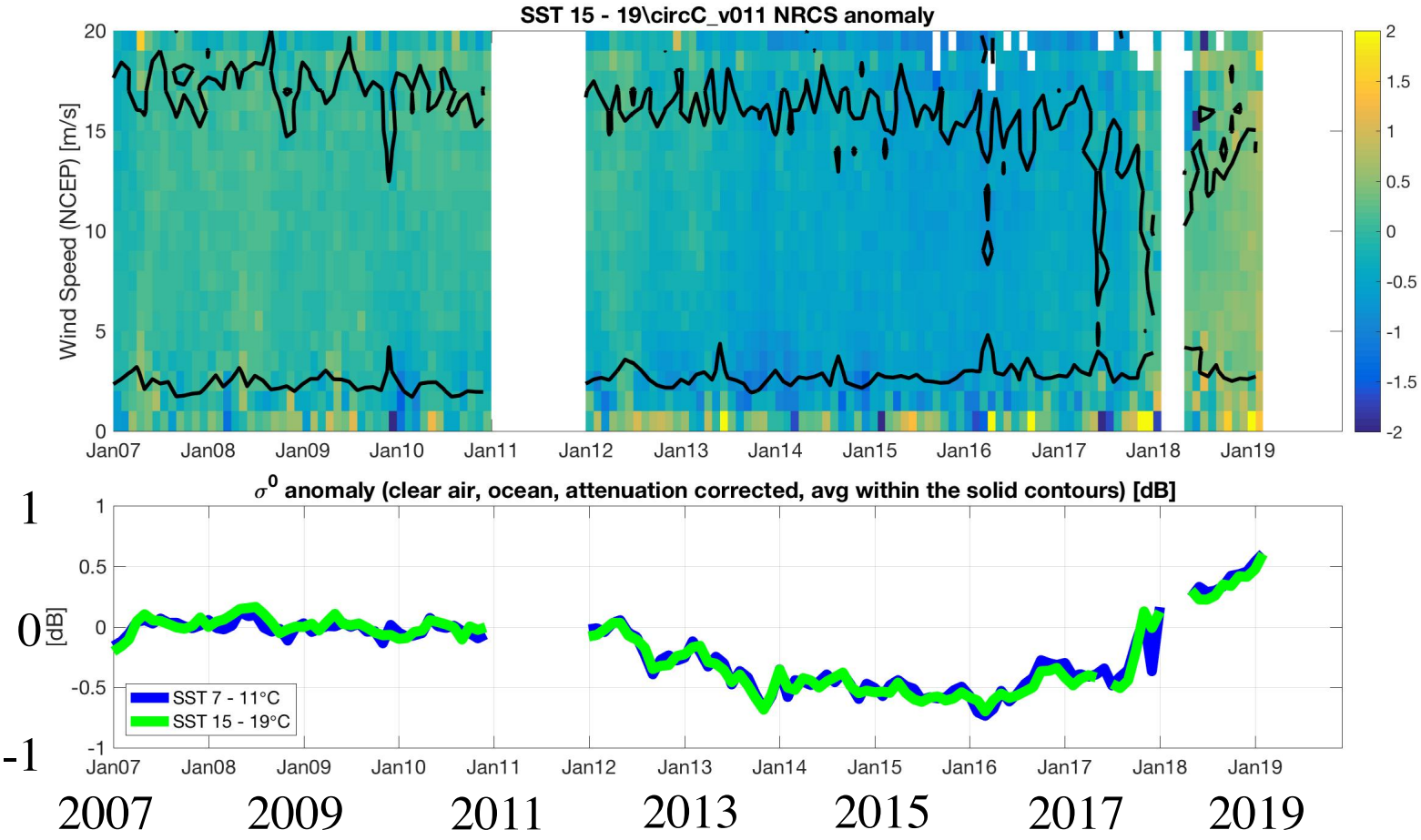
Calibration History 2007 - Present



The dip observed in L2B is a **calibration drift of ~0.5dB**. It started around the end of 2012 and ended at the end of 2013. It **affects the R04** data. It is **corrected in R05**.

CPR EIK performance recap

- **No prediction of future EIK performance is made.**
- If the current trend of a 1dB/yr drop holds, the minimum detectable signal (MDZ) will be at the EIK red limit switchover threshold of -24dBz in Jan 2021.
- CPR minimum detectable signal is based on CPR transmit power (data requires no down stream products and available near real time) and calibration drift (requires L1B and L2B-GEOPROF, results available with ~ two month lag time).
- MDZ data is processed monthly.

Post A-train Orbit Table64 Overview

- **The most recent Table64 was uploaded in Aug 2018 and has been performing nominally.**
- Table64 sets the radar timing parameters
- Flight software allows space for 51 entries of distance from Cloudsat to the surface
  - Previously, when flying in the A-Train it was set for 690km – 740km
  - The current table64 altitude range for the C-Train orbit is 680km – 730km
  - Table64 determines where the science window is relative to the surface of the earth.
    - Placing the science window too low loses bins at the highest altitude of the column which are used in noise calculation and minimum detectable signal.
    - Placing the science window too high interferes with calculating the location of the surface of the earth.
    - Following the A-Train exit, the initial Table64 placed the science window too high for R04 L2B-GEOPROF algorithm.
      - Multiple updates were made to optimize the placement of the science window.

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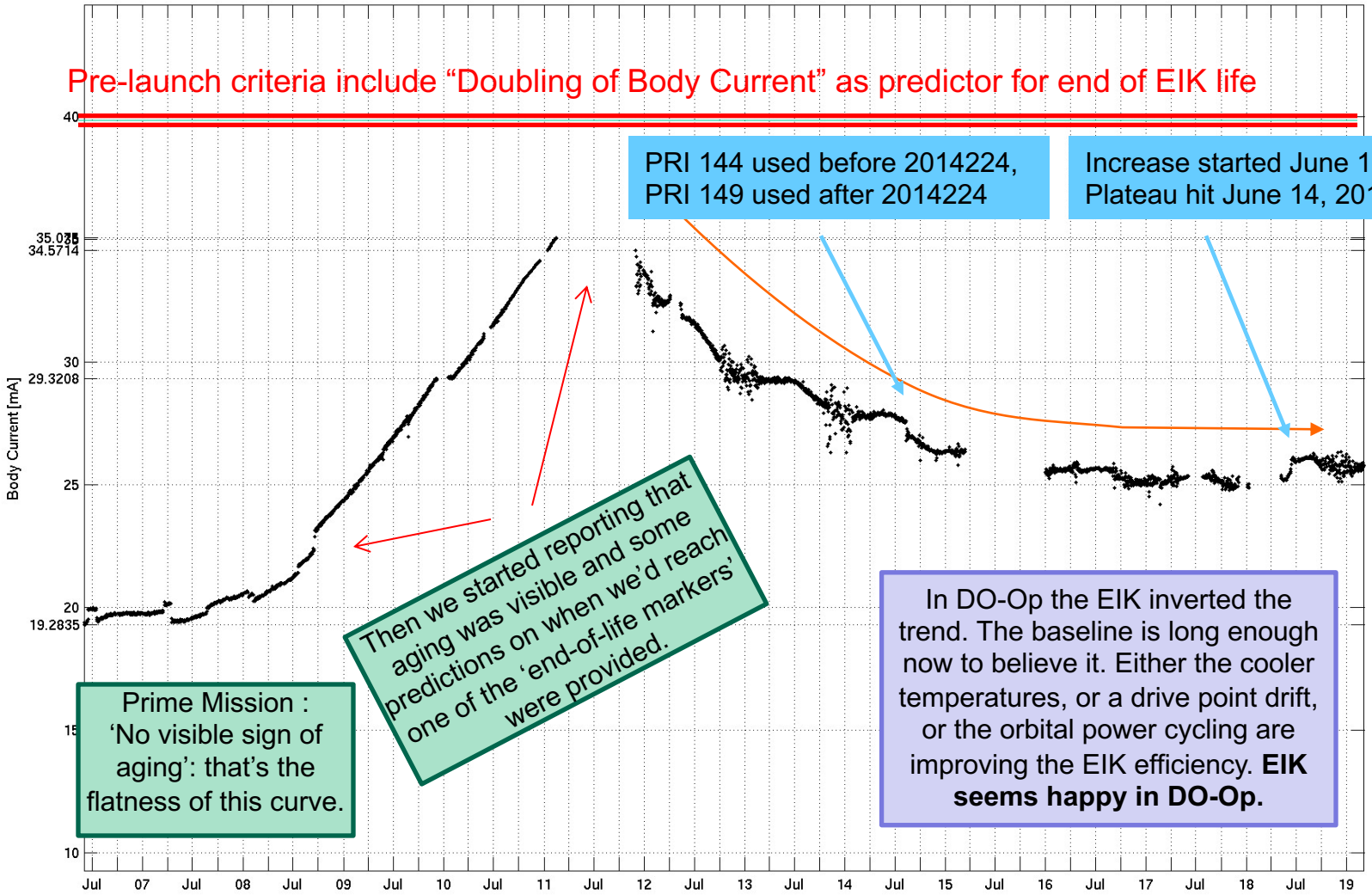
Body Current is a measure of EIK 'waste' July 2006 - Present

Tx Pwr measurements are affected by coupling variations,
but Body current (i.e., measure of 'waste' in EIK) is completely independent.



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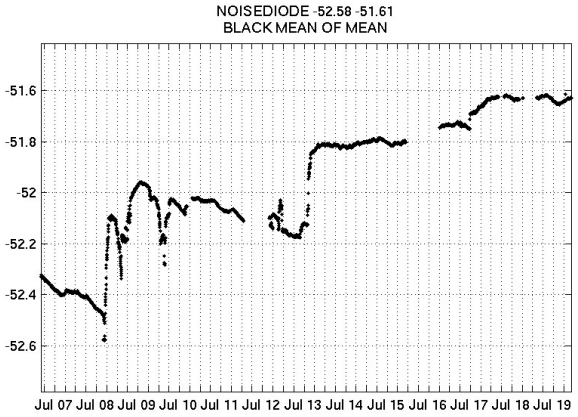
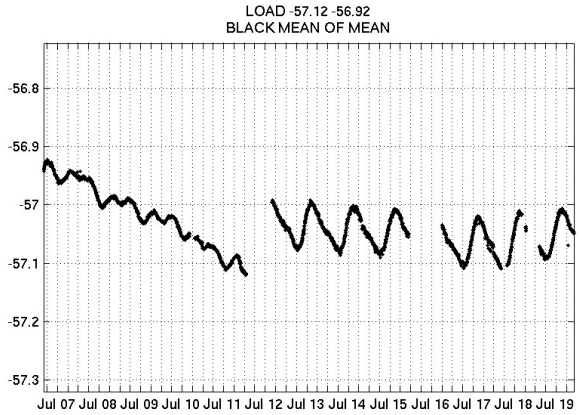
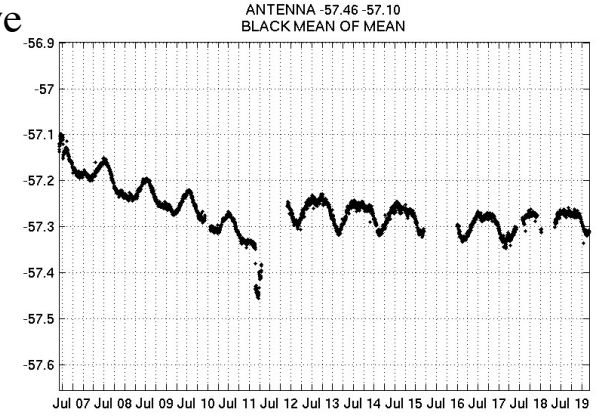
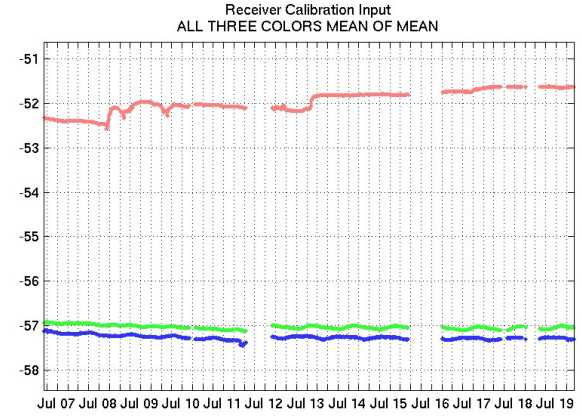
Noise Diode
July 2006 - Present

1) Noise Diode has been fairly stable over the past year.
2) It is continues to output more power than ever observed before (including ground tests).
3) No impact because we don't use its output.









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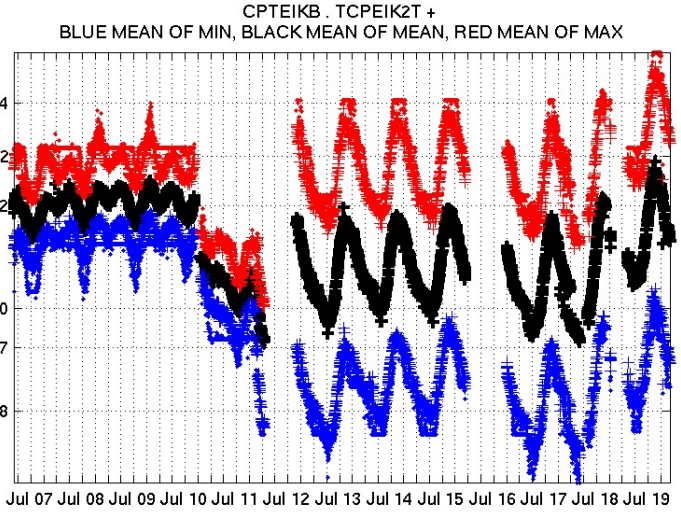
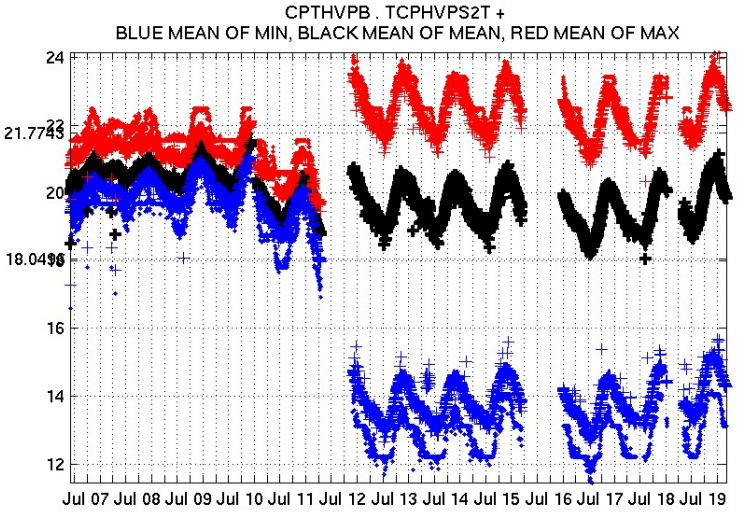
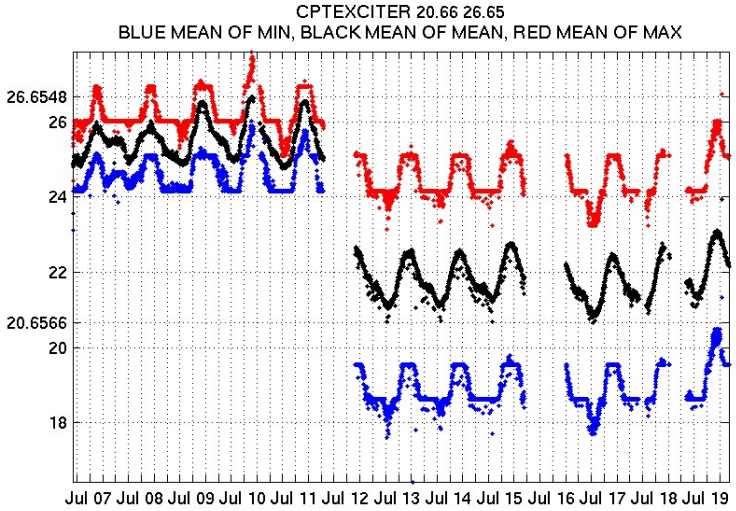
HPA2 temperatures - 13 years

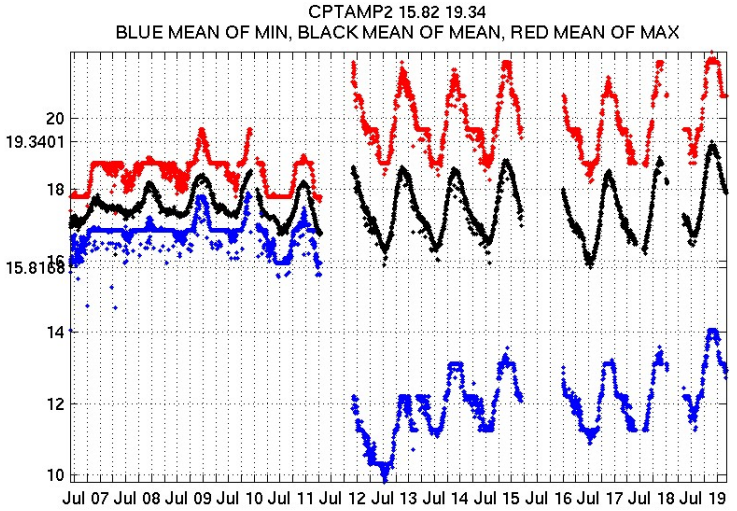
14C
EIK2



8C







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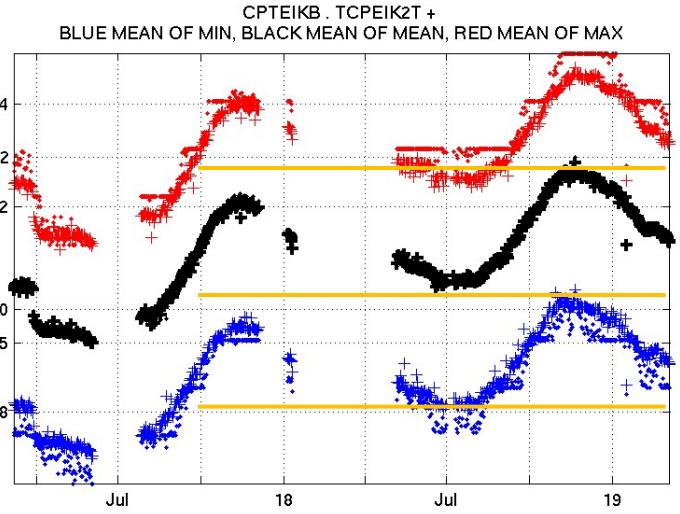
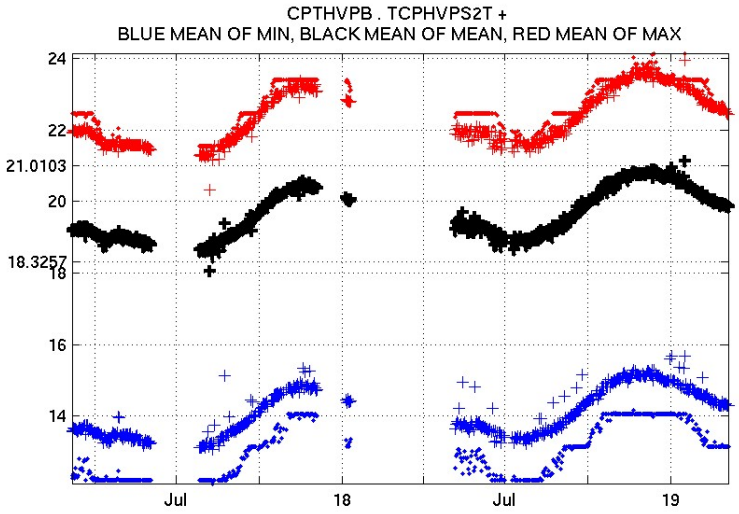
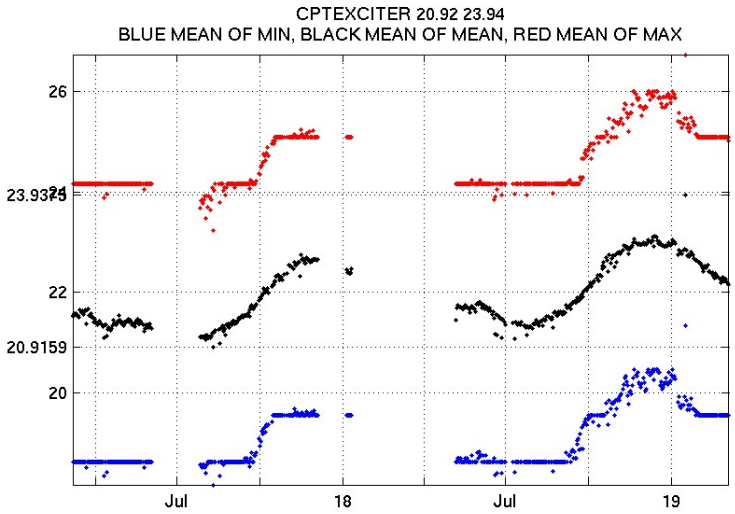
HPA2 temperatures last two years

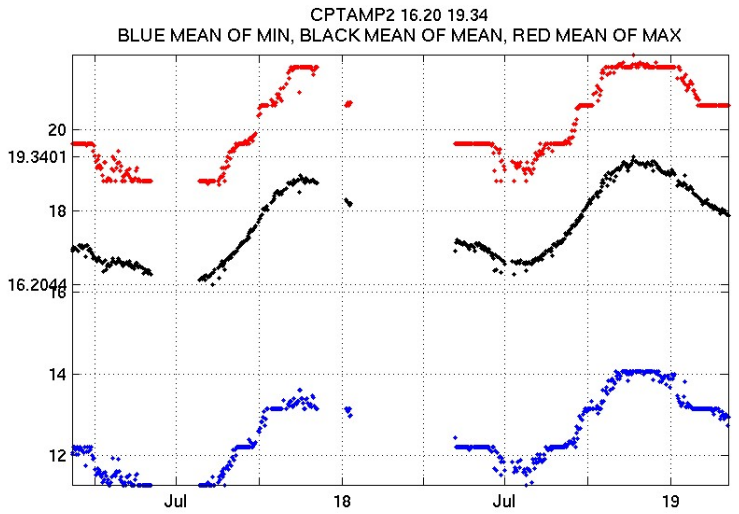
14C EIK2



8C







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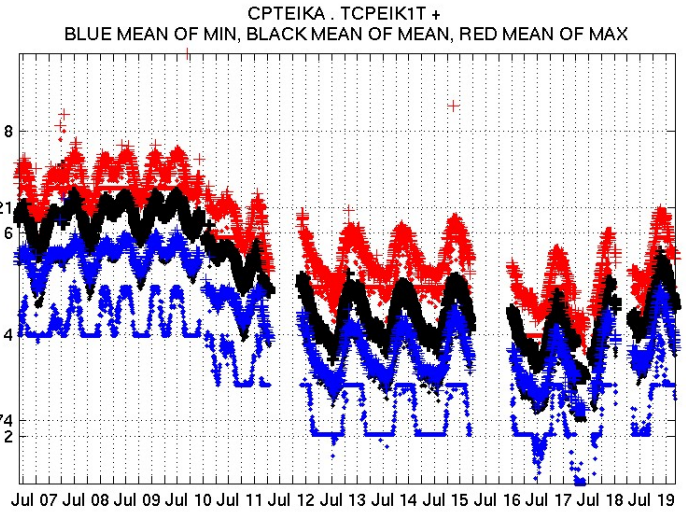
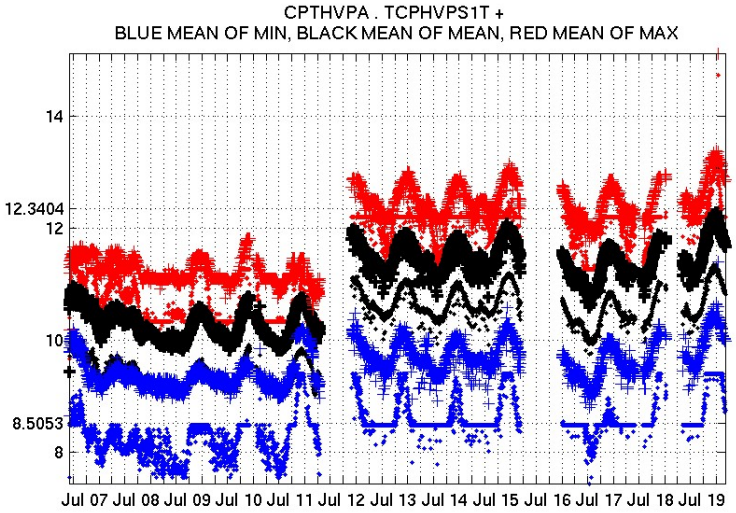
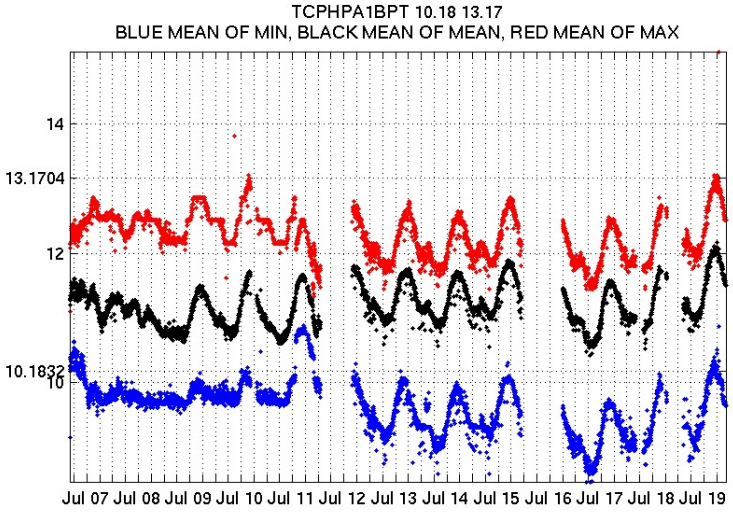
HPA1 temperatures - 13 years

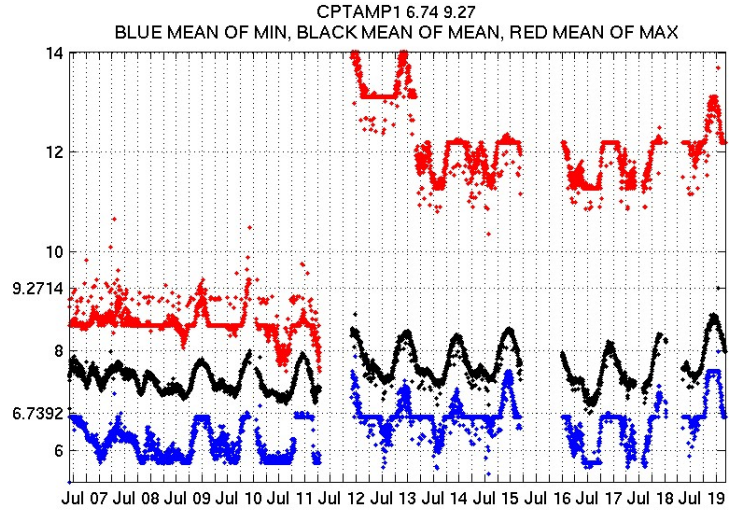
EIK1 8C



2C







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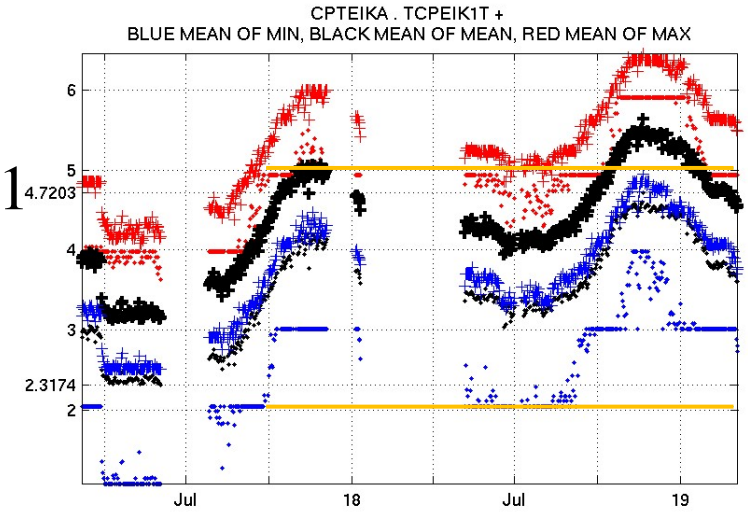
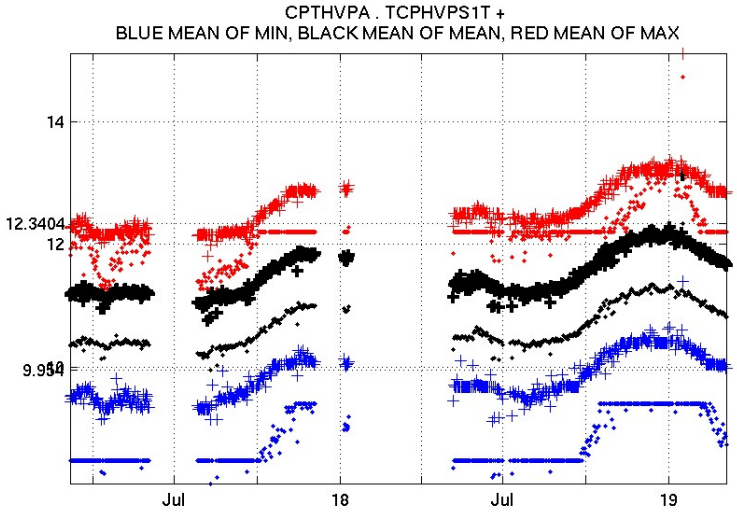
HPA1 temperatures last two years

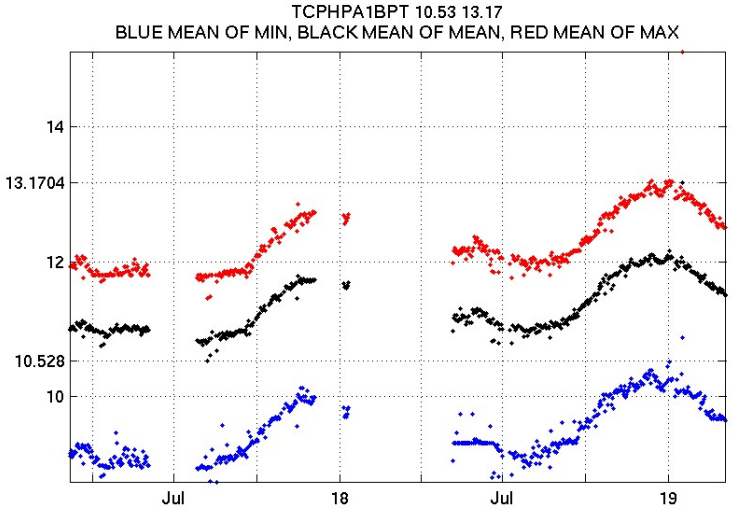
6C

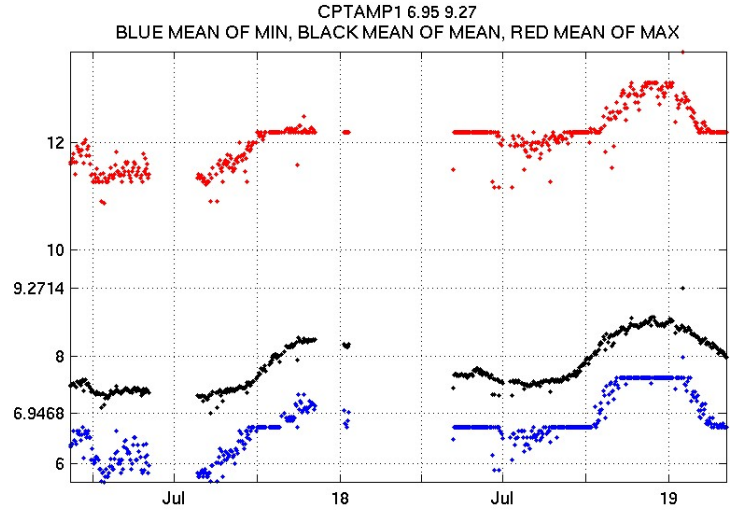
EIK1

2C









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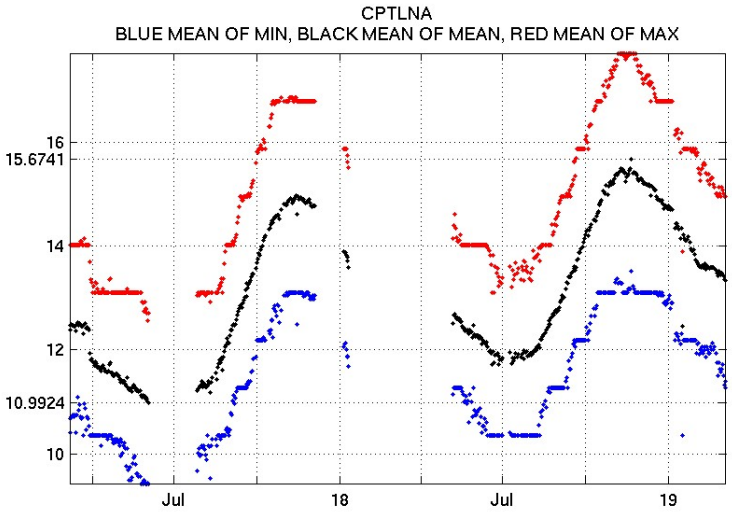
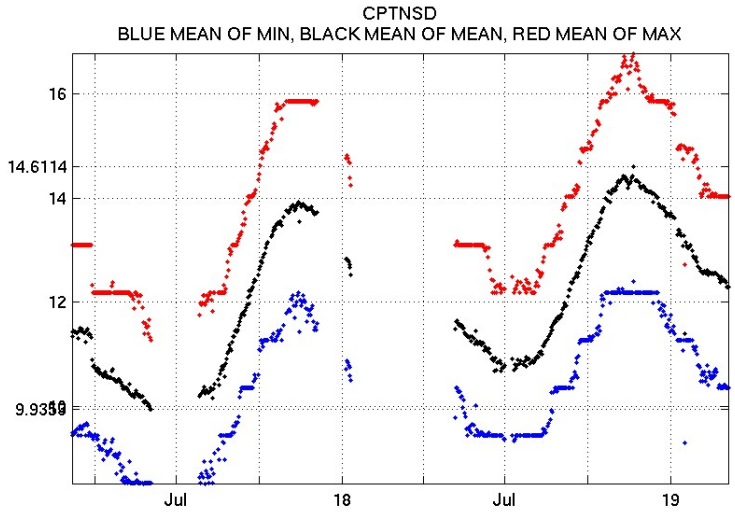
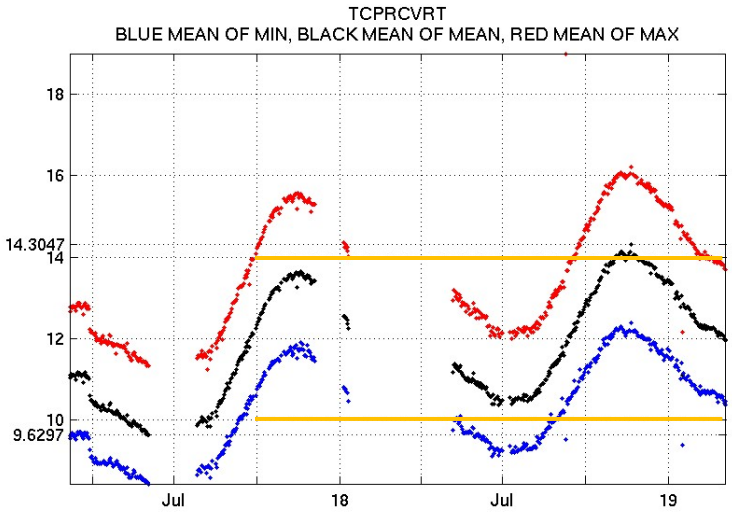
Receiver temperature last two years

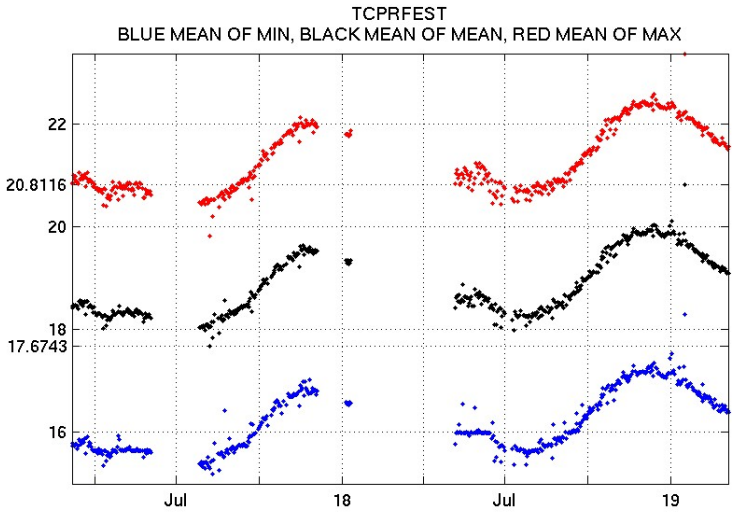






14C

10C



TCPRCVRT

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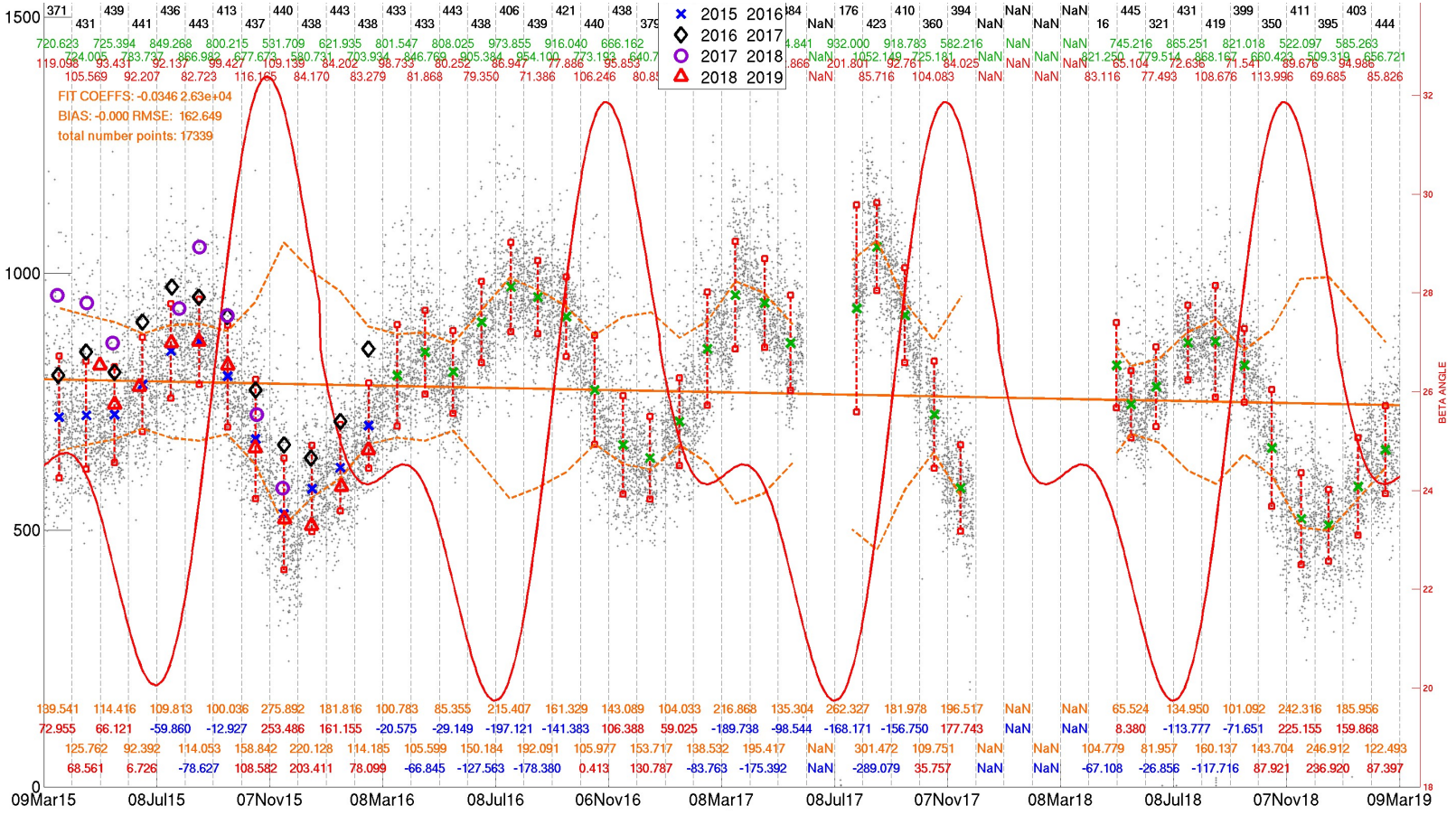
Monthly average of stability heater on time in seconds 2015-2019

A reduction of 60-90 seconds has been observed since return to DO-Op May 2018



CPR EIK switchover plan status part 1 of 2

- The plan was written with the priority to move carefully and not rush any steps.
- The CPR EIK switchover plan was presented at the RSC in Jan 2017
- Notes from the presentation:
  - The plan will be executed via CSM rather than relying on real time commanding.
    - The team has lots of experience with CSMs and this reduces the risk of human error as well as the risk of losing a connection partway though a contact.
    - No JPL-CPR engineer is required to be at the RSC during the EIK switch; being at JPL will allow more efficient work flow.
  - The plan is fairly complete and agreed upon with a few exceptions listed on the next slide.

CPR EIK switchover plan status part 2 of 2

- The CPR EIK switchover plan was presented at the RSC in Jan 2017
- Details that need to be finalized:
  - RSC, JPL-CPR, BALL:
    - Determine the amount of time required for turn around on CSMs if the RSC does not get CSMs in advance.
      - About 24 hours from CPR team requesting a CSM to implementing it on orbit.
      - Another 24 hours to download data and analyze it.
        - » Overall pace of switchover is two steps per week
        - » Given about eight steps, if all goes well with no delay, switchover takes four weeks minimum.
  - From JPL-CPR:
    - Detailed schedule pending decision on CSM implementation.
    - Determine method for testing PREP mode on side 1: ~~stay in PREP mode for several orbits to obtain thermal data at the time of the EIK switchover~~, or forego thermal data collection to move the switchover process along faster.
  - From Ball:
    - Verify what needs to be done to execute a maneuver throughout and after the EIK switchover.
    - Verify there are no changes to spacecraft fault management throughout the switchover.
    - In the various CBM sequences, account for the continuously drifting lower C-Train orbit altitude compared to the constant altitude A-Train orbit.

Analysis of 10 orbit Hip Hop test by Roger Marchand of the Cloudsat Algorithm Development Team

- After analyzing the 10 orbits of Hip Hop data from the Jan 17, 2019 test, the following assessment was made:
  - The overall impact of Hip Hop from a science perspective is small.
    - Negative impacts on science include: increase in surface clutter, increase in mismatch with CALIPSO data.
  - If implemented operationally, Hip Hop would result in flagging some profiles to note the off-nominal (violating the 0.022 degree accuracy requirement) pointing.
    - The amount of time and the magnitude of off pointing varied from orbit to orbit:
      - Off pointing time: from 1307 to 3025 profiles, out of a total of 20855 profiles per orbit.
      - Off pointing magnitude:
        - » Along track: 0.017 to 0.34 degrees (nominal is 0.16 degrees)
        - » Cross track: -0.22 to 0.19 degrees (nominal is 0 degrees)
      - On average, 2534 of 20855 profiles have off nominal pointing.
  - At the end of Feb 2019 feedback was given to the Ball team to minimize the science impact of Hip Hop operation.

Non-nominal events from the past year ending in May 2019

- Table64 (version 6.6) update due to new post-Atrain orbit May 2018
  - Updated to version 6.9 Aug, 2018 based on R04 L2B-GEOPROF data
- Cloudsat Hip Hop test Jan 17, 2019
  - Test a new variant of DO-Op to improve thermal profile of orbit to reduce wear on the battery/increase margins during high load season.
  - Test data set was sent to a subset of the science team and feedback was provided to the Ball team.

Staffing Plan

- Current technical staffing
  - Simone Tanelli, < 0.1 FTE
  - Gregg Dobrowalski, ~0.75 FTE because of other urgent commitments
  - Cody Vaudrin, ~0.15 FTE
  - Steve Durden, << 0.1 FTE
  - CPR Cog-Es: on demand or thermal and mechanical engineering. <<0.1 FTE

- Back up

Table64 overview

- Table64 sets the radar timing parameters
- Flight software allows it space for 51 entries of distance from Cloudsat to the surface
  - If the Cloudsat orbit goes beyond the current Table64 the following action is taken: "Should the geodetic altitude go out of range of the values shown in the table the spacecraft shall default to the closest table value and respond with an out of range flag in telemetry"
    - No harm is done to the radar in this case. Degradation of science data occurs if the Cloudsat orbit is out of range of Table64.
  - If the Cloudsat orbit varies more than 50km, the parameters could be set at a coarser resolution to cover the range.
    - Altitude is stored as a float; it does not have to be an integer value.

Post A-Train Table64 Version Control

- Since departing the A-Train, several table64 updates were made, all tables covered the same 680km – 730km altitude range:
  - Table64 v6.6 created April 30, 2018: new altitude range for post A-Train orbit
  - Table64 v6.7 created June 27, 2018: previous v6.6 led to some bad output values in R04 L2B-GEOPROF. Looks to be a software issue, under investigation.
  - Table64 v6.8 created July 26, 2018: previous v6.7 did not fix all the issues of v6.6, v6.8 was the next correction.
  - Table64 v6.9 created August 27, 2018: v6.9 added more margin to the placement of the science window. v6.9 has been performing nominally.

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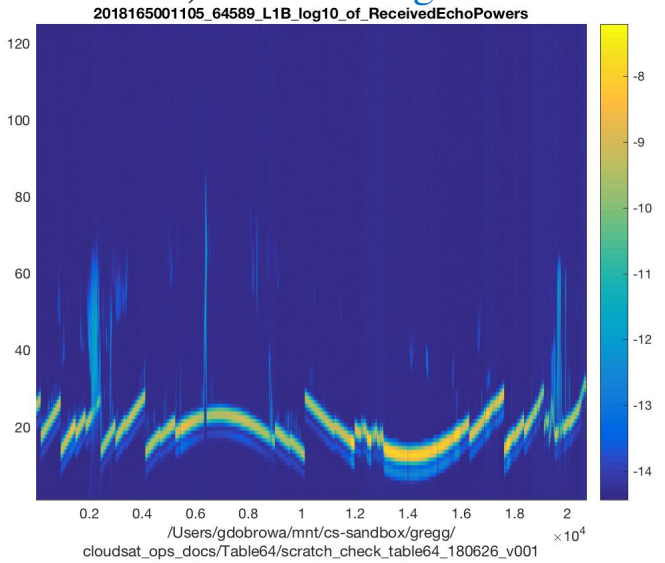
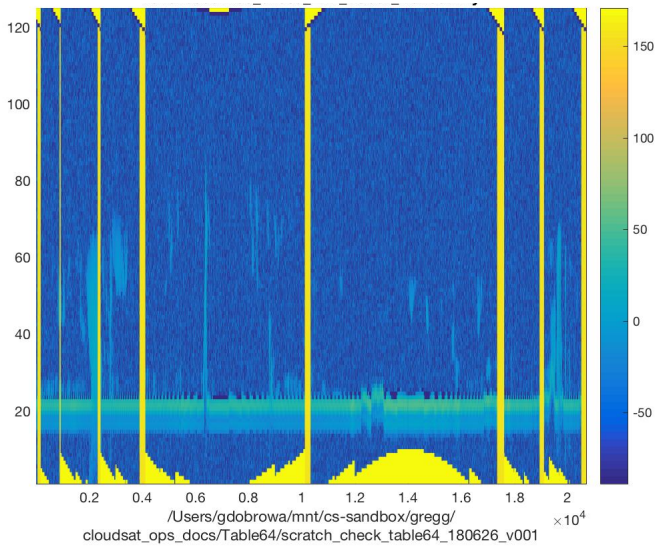
Recent Table64 post A-train data May 2018

- By JPL request, CIRA ran R04 algorithms for L1B and L2B-GEOPROF. Unexpected fill values are seen in the **R04** L2B-GEOPROF data using table64 version 6.6 (May 2018).
  - This is being investigated
  - A run of R05 algorithms is in the works
- New table64 (version 6.7) uploaded July 9th, 2018 should eliminate the conditions where fill values are seen in R04 L2B-GEOPROF
  - When the surface is too close to the start of the data window, fill values are observed.
  - New table64 (version 6.7) transmits fewer pulses to keep surface in better position in data window.
- **This is a software issue, as the data is seen in the L1B product.**

R04 L1B log10(Received Echo Powers) table64 6.6 granule 64589

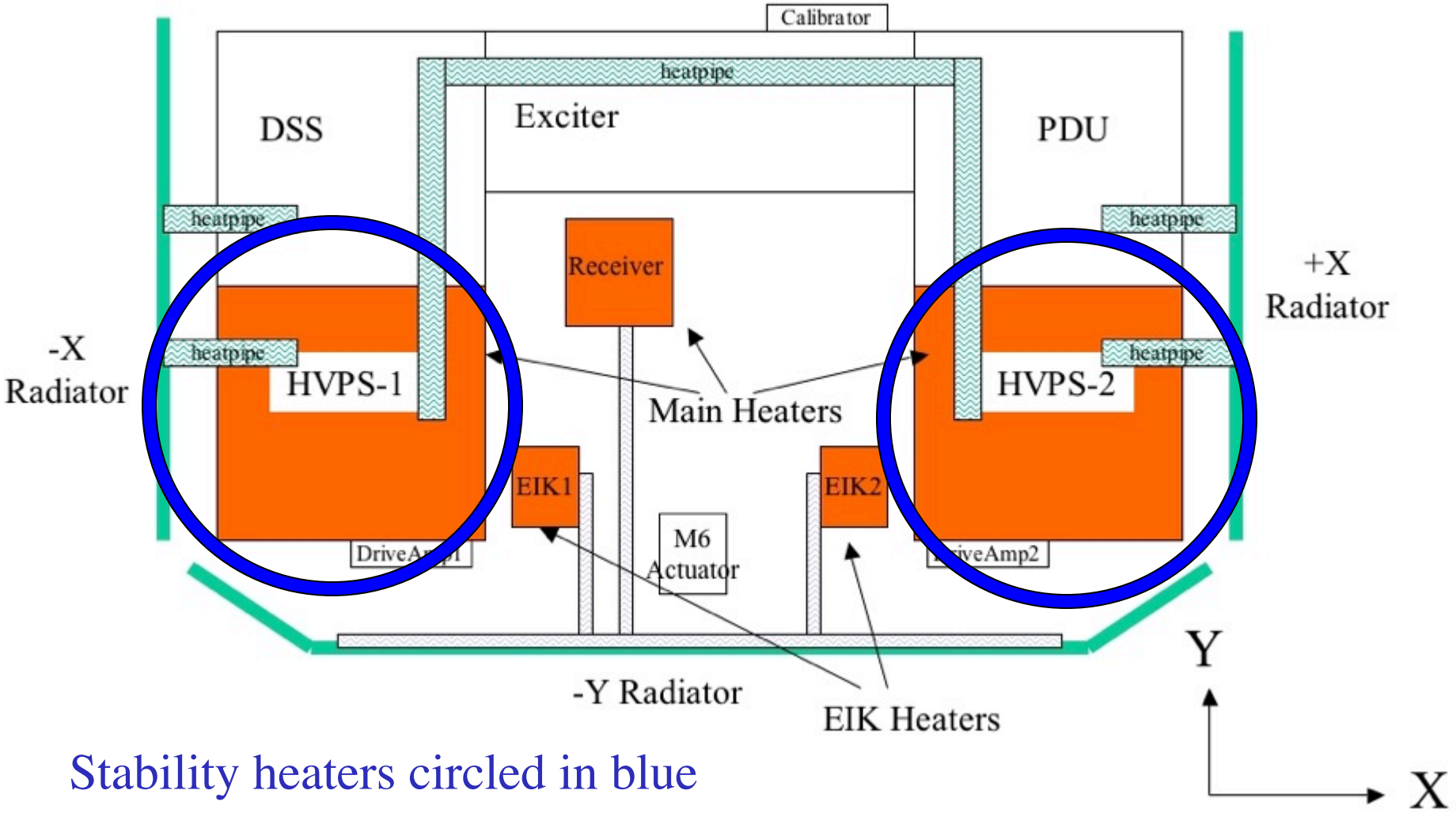


R04 L2B-GEOPROF Radar Reflectivity table64 6.6 granule 64589



EIK (80 Watts) and Main Heaters (136 Watts)

Commanded by CPHON/CPHOFF + (CPEIKHON/CPEIKHOFF & CPMHON/CPMHOFF), Req. SMB ON



Stability heaters circled in blue

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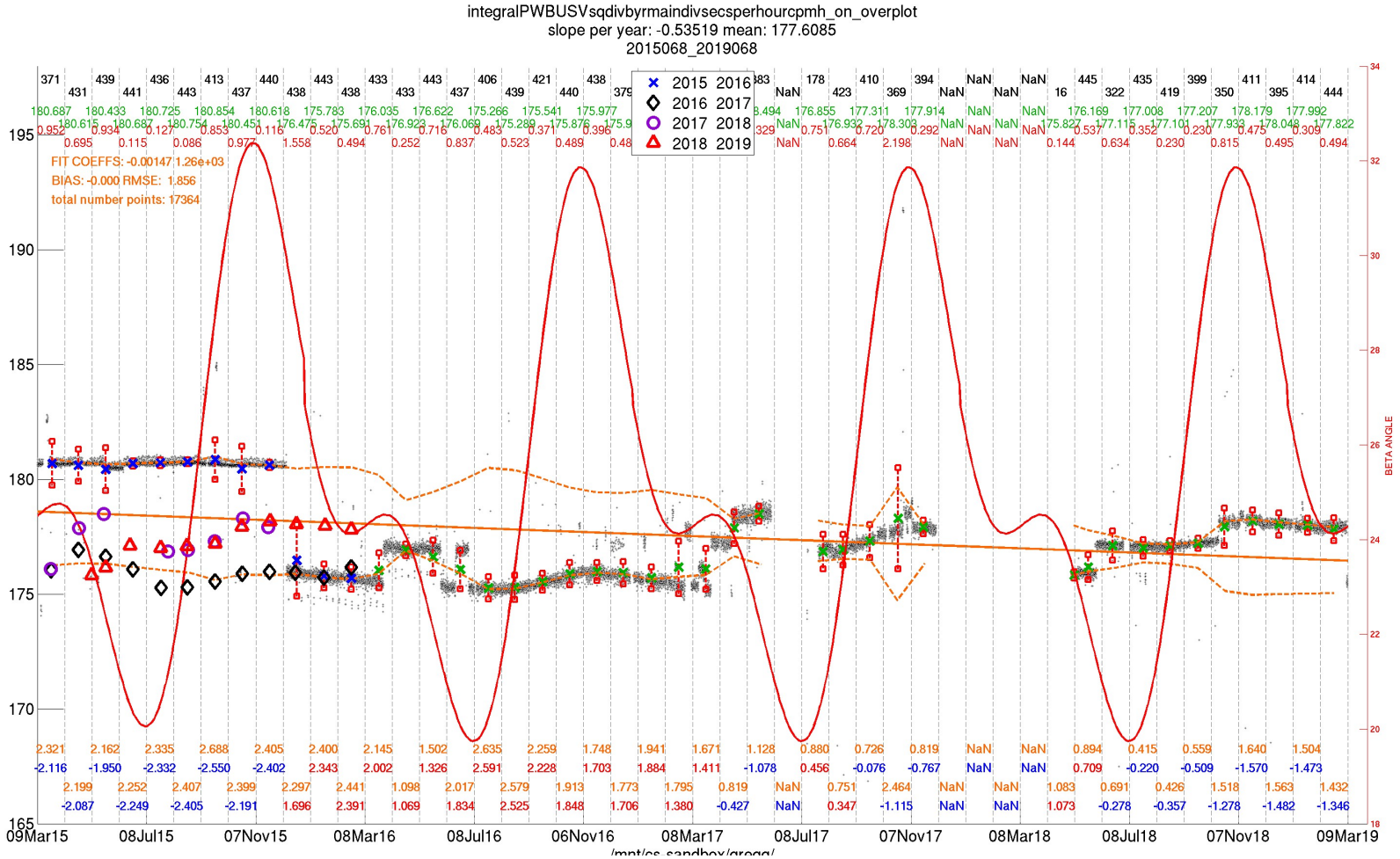
Monthly average of Watt hours of CPR main heater on 2015-2019



2016 2017 2018 2019

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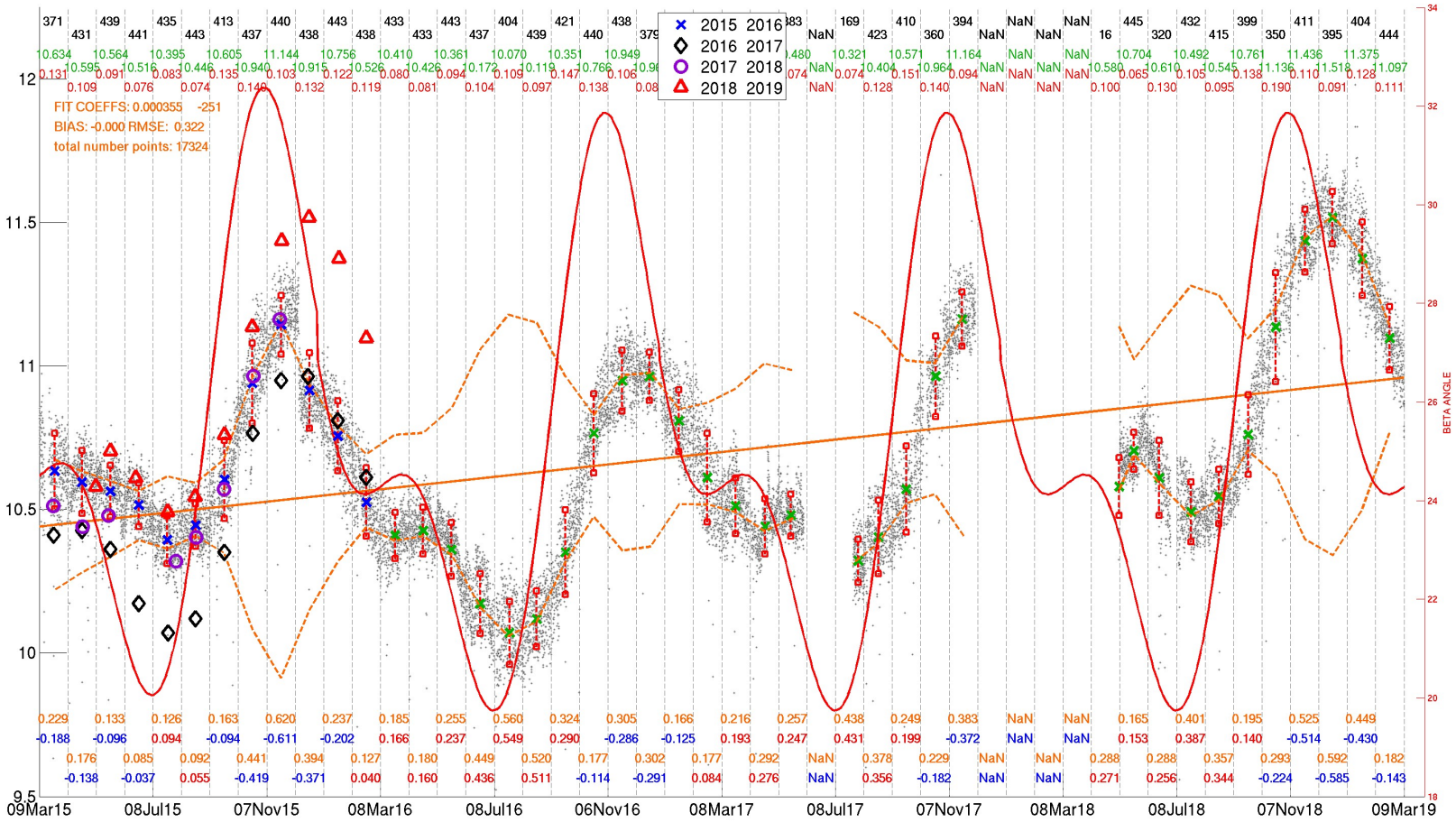
Monthly average of TCPHPA1BPT 2015-2019

An increase of about 0.2C has been observed since return to DO-Op May 2018, compared to May 2017



2016 2017 2018 2019

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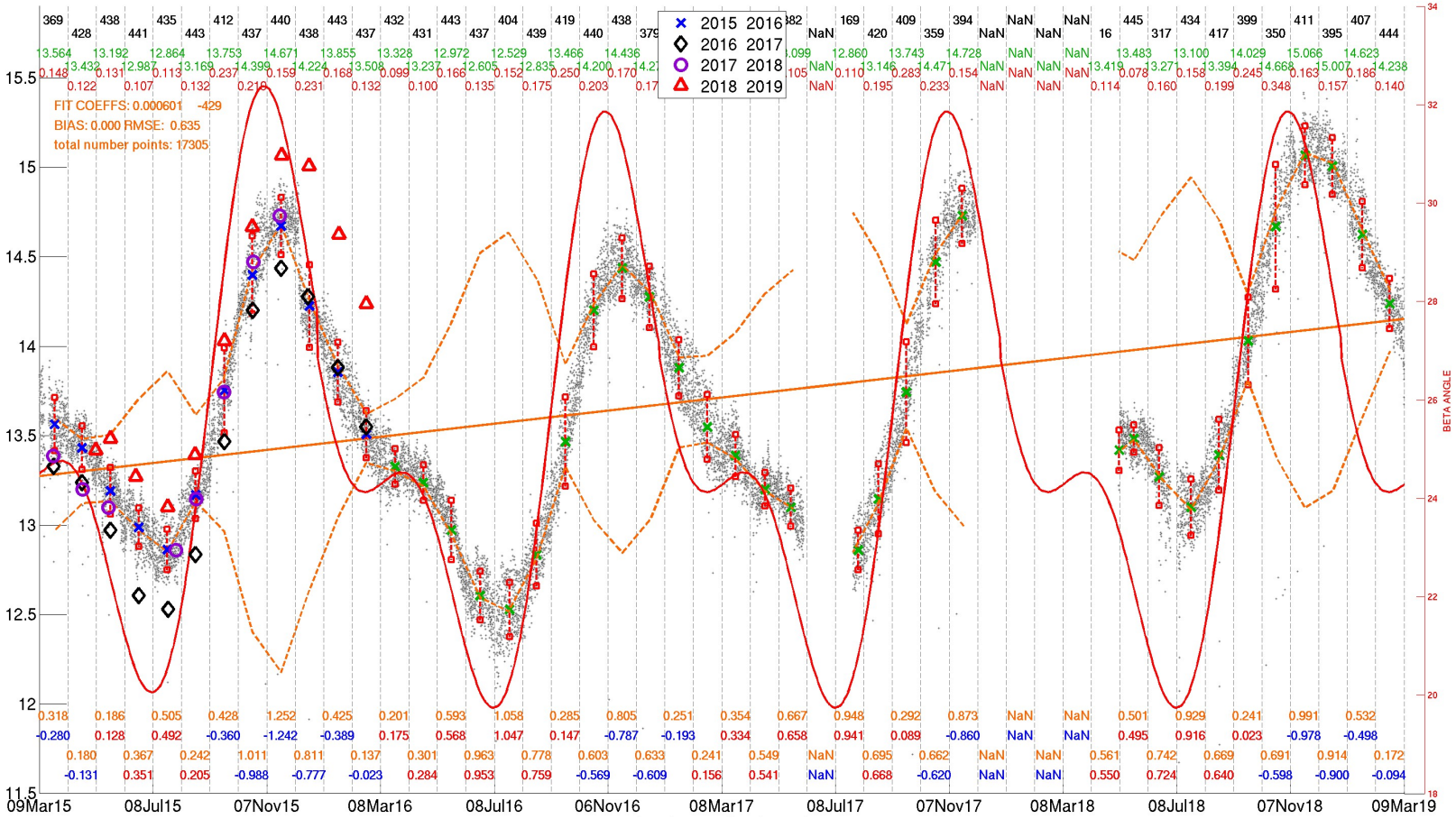
Monthly average of TCPHPA2BPT 2015-2019

An increase of about 0.2C has been observed since return to DO-Op May 2018, compared to May 2017



2016 2017 2018 2019

Battery charging method timeline 2013 - 2017

- 2013
  - VT 5.0 enabled Feb 26, 2013, previously VT 5.5 was used
- 2014
  - VT 5.5 enabled May 22, 2014
- 2015
  - VT 5.0 enabled Feb 25, 2015
  - MMKI 5.5 enabled Dec 12, 2015
- 2016
  - MMKI 6.0 enabled Mar 29, 2016
  - MMKI 5.5 enabled May 31, 2016
- 2017
  - Long Duration SASSI5.0 with KI Boost test start Mar 29, 2017
  - Deep discharge Oct 29, 2017
  - MMKI5.0Boost17.5 Nov 8, 2017

Battery charging method timeline 2018 - 2019

- 2018
  - MMKI5.0Boost17.5 Jan 4, 2017
  - MMKIVT5.0 in enhanced SPS Jan 12, 2018
  - Return to DO-Op MMKI5.5Boost17.5 May 7, 2018
  - MMKI5.5Boost17.5 VT stepping implemented Jun 1, 2018
  - MMKI5.5Boost17.5 VT stepping 5 min delay 1 day trial Jul 26, 2018
  - MMKI5.5Boost15 VT stepping 3 day trial Oct 16-19, 2018
  - MMKI5.5Boost15 VT stepping implemented Oct 19, 2018
  - MMKI5.5Boost12.5 VT stepping implemented Nov 2, 2018
  - MMKI5.5Boost10 VT stepping implemented Nov 13, 2018
- 2019
  - No charging changes as of Mar 13, 2019

Overview of EIK switchover

- The step numbering convention is taken from the EIK checkout CBM:
  - CS_Table21_CBM_Rdnt_EIK_Switch_v**4**.xlsx

- Step 0: Upload EIK checkout CBM
  - written on the currently unused side of Block 4d
- Step 1: Move mirror & Step 2: Receiver Protect test
- Step 3: Receive only for 10 minutes (first time of turning on High Voltage Power Supply side one on orbit)
- Step 4: Operate for 5 minutes (first time operating side one on orbit)
- Step 5: Operate for 55 minutes (one orbit then 24 hours)
  - Step 5 is the last step in the EIK checkout CBM block
- Step 6: PREP mode on side one
  - overwrites block 6 which previously contained PREP mode on side two
- Step 7: DO-Op on one section of block 4d (one orbit then 24 hours)
  - overwrites the EIK checkout CBM
- Step 8: DO-Op on the other section of block 4d (one orbit ~~then 24 hours~~)
  - overwrites the section of block 4d that had most recently been used for DO-Op using HPA side two

Taken from:20171107_eik_switchover_walk_through_v001.pptx

Tentative EIK switchover schedule

- No activities are scheduled to execute on orbit on any Thur., Fri., Sat., or Sun.

- Week 1:
  - Step 0 on Mon
  - Steps 1 and 2 can be done in parallel on Wed.
- Week 2:
  - Step 3 on Mon.
  - Step 4 on Wed.
- Week 3:
  - Step 5 on (one orbit) Mon.
  - Step 5 (24 hours) on Wed.
- Week 4:
  - Step 6 on Mon.
  - Step 7 (one orbit) on Wed.
- Week 5:
  - Step 7 (24 hours) on Mon.
  - Step 8 (one orbit) on Wed.
- Week 6:
  - Long term DO-Op on side one on Mon.

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Events of Oct 29, 2017

- CPR modes for the day:
  - DOOP1 (mode 3 on the plot) for 1+ orbits
  - DOOP2 (mode 4 on the plot) for 10 orbits (deep discharge observed)
  - STANDBY (mode 2 on the plot) for 2 orbits
  - PREP (mode 5 on the plot) for 2 orbits

- DO_Op2, @ ~01:58 UTC
- CPR main heater was unintentionally left on throughout eclipse for 10 orbits of DOOP.
  - **Max TCPHVPS2T of 27.51C observed**; the previous orbit was 27.12C – still increasing after 10 orbits.
    - **Nominal max is 22.66C**, taken from 17291
    - **Nominal min is 13.9C**, taken from 17291
  - **Max TCPHPA2BPT of 21.23C observed**; two orbits prior was 20.87C – still increasing after 10 orbits.
    - Per ppt CPRspecTrain012006_PrintVEr_repaired: TCPHPA1BPT and TCPHPA2BPT must not exceed 33 degrees
    - **Nominal max is 17.03C**, taken from 17291
    - **Nominal min is 11.1C**, taken from 17291
- 16:49 UTC
  - Standby was commanded once the unexpectedly large discharge current was noted.
- 20:41 UTC
  - First orbit of PREP enabled

- 10 orbits of deep discharge.
- Battery discharge current during eclipse 7.27 to 7.86A
- Min BUSV did not collapse but decreased from the typical 29.6V to 26.4 with a min P1B1V = 26.66V, just above the UV2 Limit of 26.5
- After one orbit of CPR main heater on, CPR stability heater might have not come on due to CPR temps rising from the CPR main heater
- Increase in CPTEIK1T during two orbits of standby is consistent with behavior from Feb 26, 2017 when Cloudsat went to STANDBY for lunar transit

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SSOH files from 17302: Oct 29, 2017
17301 10/28 22:25 through 10/29 23:02

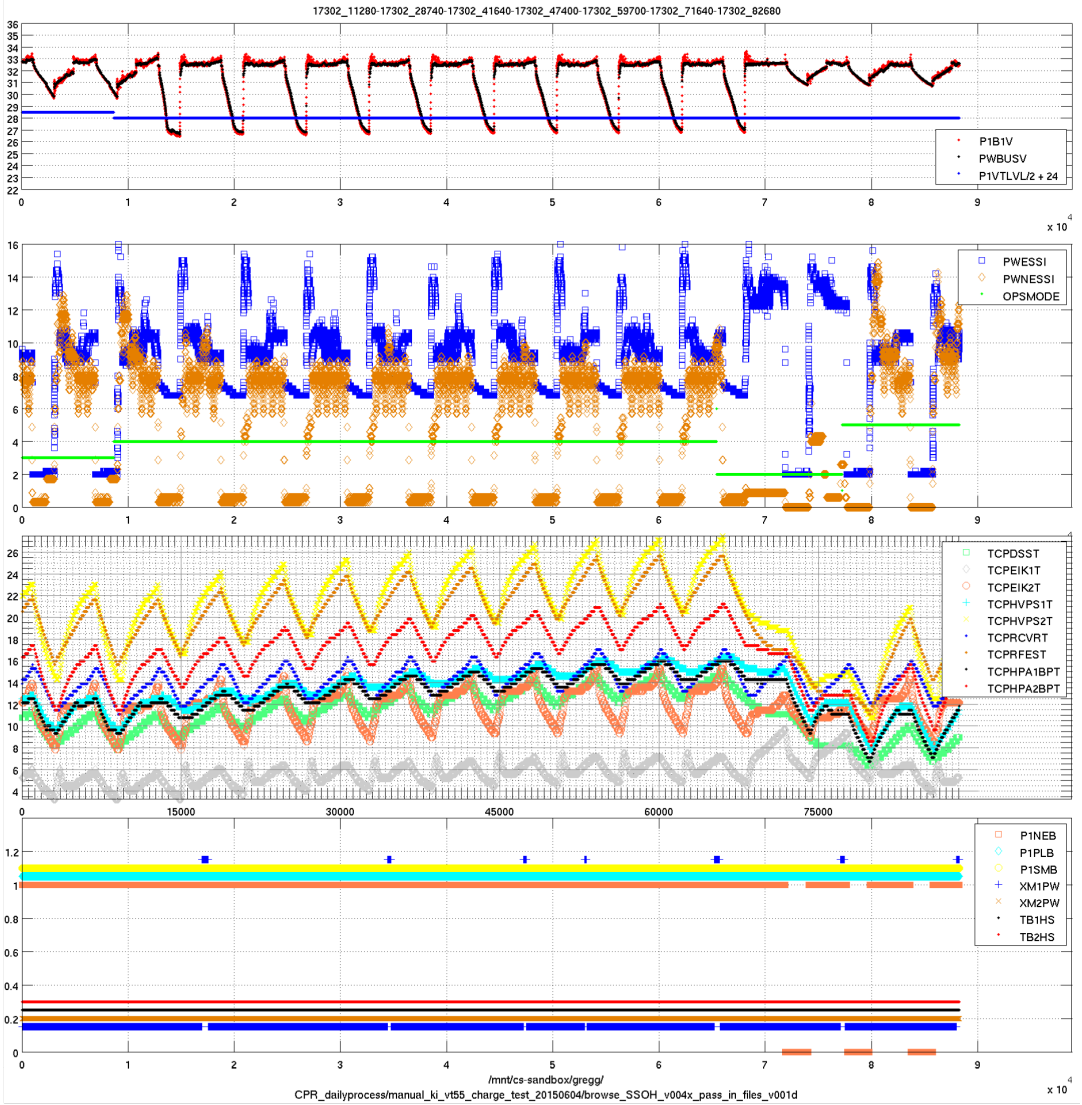

Table64 notes

- Per data sheet from Brian Pieper provided Jul 10, 2018 about how table64 is stored on board: altitude and PRF are floats; PRI, EIF, DWD, and PTT are integers.

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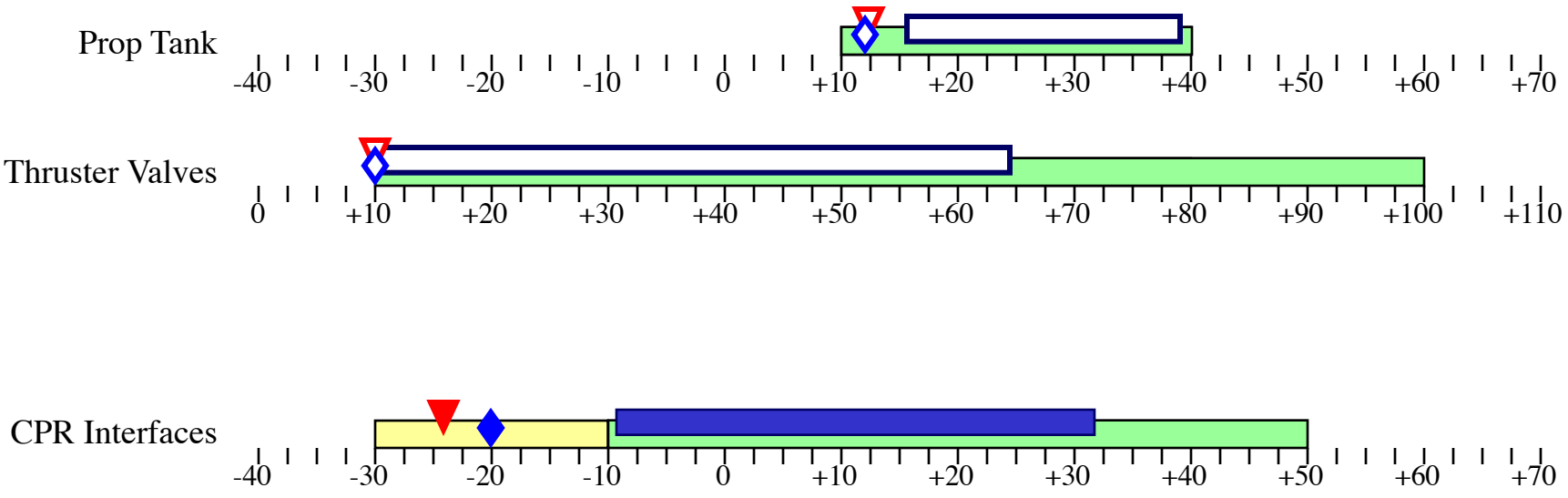
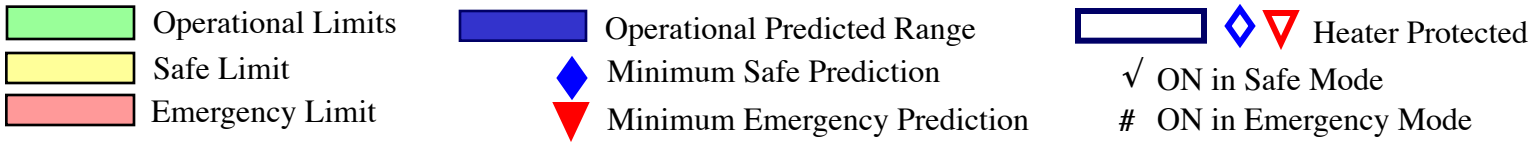
Flight Temperatures: Propulsion & CPR I/Fs





Non-nominal events from the past year ending in May 2018

- CPR main heater on for 10 orbits Oct 2017.
  - CPR temperatures increased as expected but still within safe range.

- Precision External Clock (PEC) has a heater issue that started in December 2017.
  - Only effect on CPR is more frequent Table 2 updates

- December 5, 2017 payload bus was off from UV3; was not turned on before attempting return to PREP end of Dec 2017.

- Table64 (version 6.6) update due to new post-Atrain orbit May 2018
  - Updated to version 6.7 July 9th, 2018 based on R04 L2B-GEOPROF data